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WATER QUALITY IN SUBMARINE BASINS OFF SOUTHERN CALIFORNIA

Donald R. Menard

Federal Water Pollution Control Administration
San Francisco, California

November 1968

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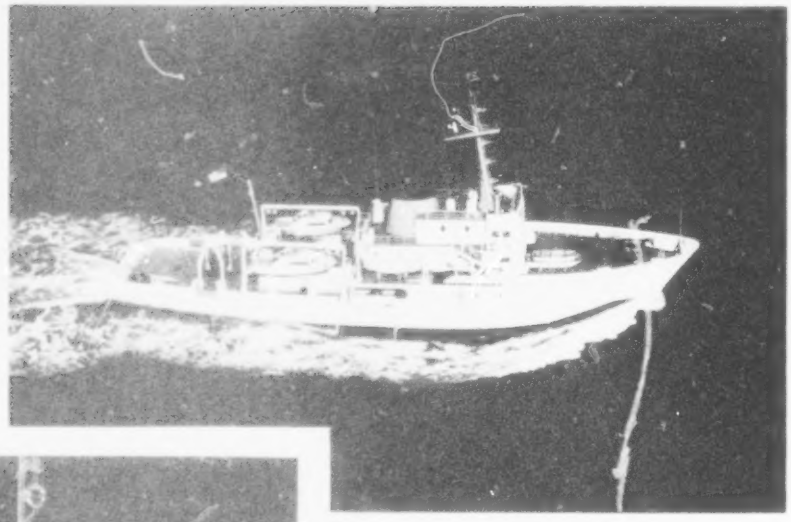
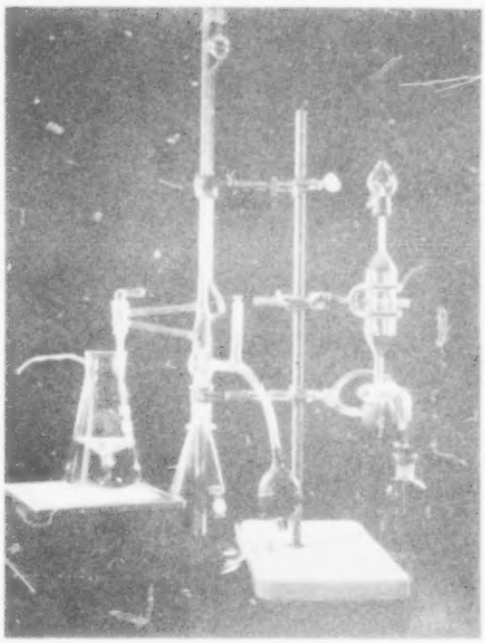
PACIFIC SOUTHWEST REGION





WATER QUALITY IN SUBMARINE BASINS OFF SOUTHERN CALIFORNIA

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WATER QUALITY IN

SUBMARINE BASINS OFF SOUTHERN CALIFORNIA

U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER QUALITY ADMINISTRATION
PACIFIC SOUTHWEST REGION

November 1968

Abstract

A survey of dissolved oxygen, salinity, temperature and nutrient values was made in the Santa Monica and San Pedro Basins off the coast of Southern California.

Comparison with earlier data indicates no significant changes since at least 1937. The average dissolved oxygen concentration within the basins is approximately 0.20 ml/l, with levels near the floor of less than 0.10 ml/l. A sediment core from the Santa Monica Basin indicates that burrowing organisms have been absent for more than 50 years.

The low oxygen levels evidently result from the coincidence of the depths of the sill and the oxygen minimum zone in the ocean, the restricted circulation of basin waters, and the oxidation of organic bottom sediments.

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I. INTRODUCTION

BACKGROUND, PURPOSE AND SCOPE

In December 1966, oceanographers from the U. S. Navy Electronics Laboratory in San Diego observed what they later reported as a desert condition on the floor of the San Pedro Basin near Santa Catalina Island. During two dives in a deep submersible research vehicle the same conditions were found at locations half a mile apart. The observers noted a layer of fine brown flocculent material overlying the natural sediments, and occasional dead fish and squid in various stages of decomposition. Worm tubes were numerous, but no worms could be seen. A water sample taken 6 inches from the bottom showed the dissolved oxygen content to be 0.03 ml/l (about 0.04 mg/l).

The basic objective of this study was to determine whether the observed near-anoxic condition differed markedly from dissolved oxygen concentrations reported in earlier data. Supplementary objectives included a) an examination of the basin water density through temperature and salinity measurements to determine whether any changes in the water masses have occurred within recent years; b) an analysis of bottom sediments to identify the reported flocculent material and to seek indications of benthic activity; c) measurements of nutrient concentrations; and d) a presentation of data collected to use as background information for future evaluations of man's changes to the environment.

ACKNOWLEDGEMENTS

The Federal Water Pollution Control Administration received invaluable assistance and cooperation from the U. S. Coast and Geodetic Survey which provided the use of a ship on two occasions for sample collecting. Captain K. W. Jerrers and the officers and men of the USC&GSS Davidson were most helpful during these cruises.

Gerald Burke, FWPCA, assisted in the water sampling during the first cruise and in the dissolved oxygen analyses. Nutrient analyses were performed under the direction of David Wood, FWPCA. The coring operations during the second cruise were conducted by Andrew Soutar, Erich Duffrin and Bill Preslan, all of Scripps Institution of Oceanography. This report was prepared and written by David R. Minard, FWPCA.

II. SUMMARY AND CONCLUSIONS

Dissolved oxygen concentrations measured in the San Pedro and Santa Monica Basins in February 1968 were essentially the same as those measured in 1937 and 1954. Values below the sill depth (736 meters) varied from less than 0.10 ml/l to 0.30 ml/l, with an average of about 0.20 ml/l.

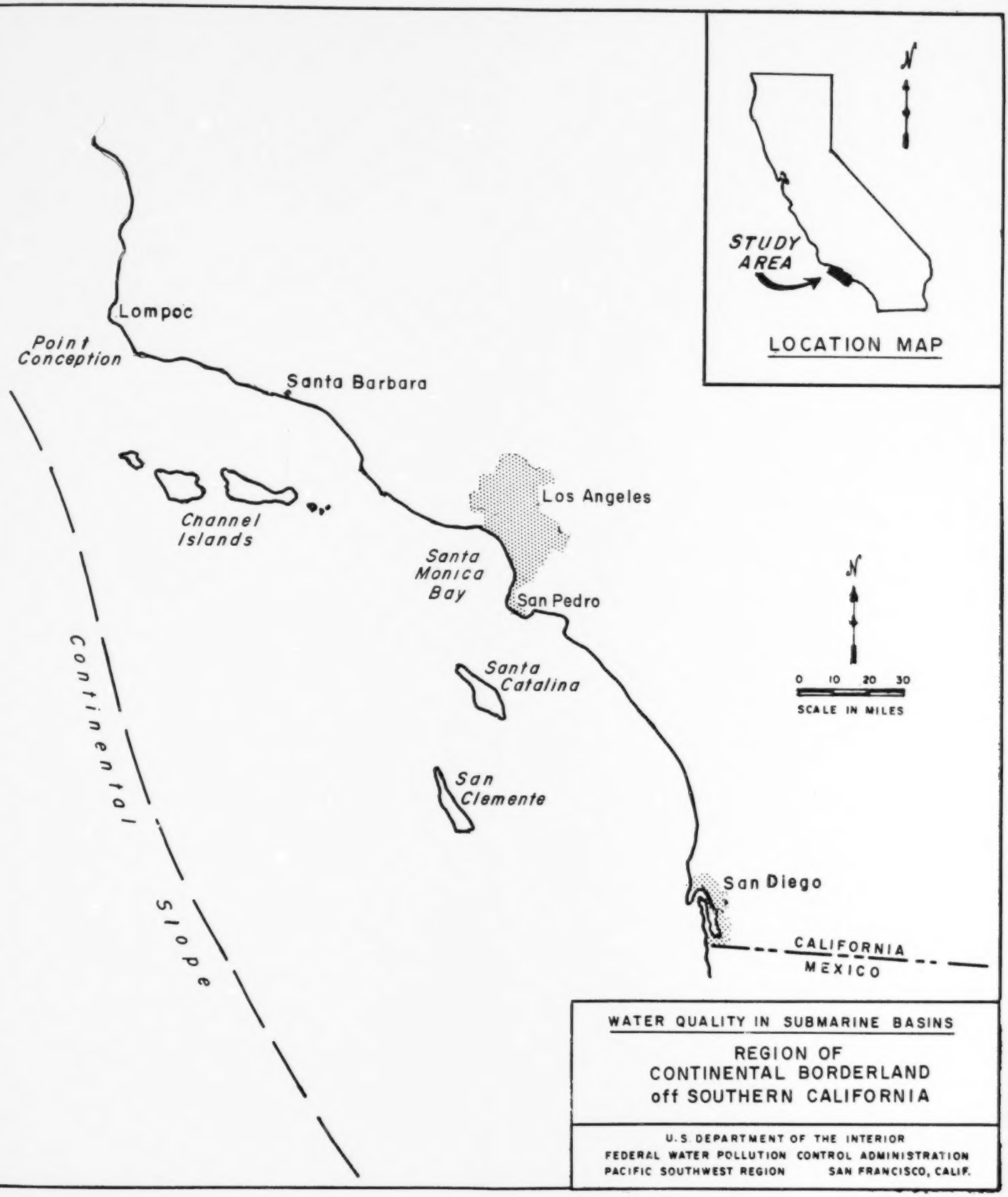
Early salinity data are somewhat contradictory. Measurements made in 1937 in the San Pedro Basin are the same as the present values, but measurements made in the 1950's are from 0.047 o/oo to 0.106 o/oo lower than present values, depending upon the location.

Orthophosphate concentrations in samples obtained near the basin floors in February 1968 were found to be the same as those measured in 1954; while nitrate-nitrogen and silicate values were 60% of those found in the 1954 samples. The 1954 nutrient concentrations were very close to average values found in the northeastern Pacific Ocean at the same depth.

A sediment core obtained during the study near the center of the Santa Monica Basin showed a 50-year history of well defined layering. Such a mode of sedimentation indicates the absence of burrowing organisms typically found in the deep ocean. A similar core taken in the San Pedro Basin showed the same layering over the last 12 years, but its earlier sedimentation mode was partially obscured as a result of sample processing.

The bottom portion of both sediment cores appeared to be homogenized and show indications of burrowings. A few worm tubes were found on the surface of each, but the fine brown flocculent material reported by the NEL oceanographers was not detected.

The occurrence of very low oxygen levels in the Santa Monica and San Pedro Basins is a natural phenomenon related to the coincident depth of the basin sill and the oxygen minimum zone typically found in the northeastern Pacific Ocean. The absence of the usual forms of benthic life is to be expected in this situation; the fact that they did not suddenly disappear in recent years is borne out by the long period of undisturbed layering in the core from the Santa Monica Basin. The nektonic organisms observed on the basin floor apparently died in the upper layers of the ocean.



WATER QUALITY IN SUBMARINE BASINS

REGION OF
CONTINENTAL BORDERLAND
off SOUTHERN CALIFORNIA

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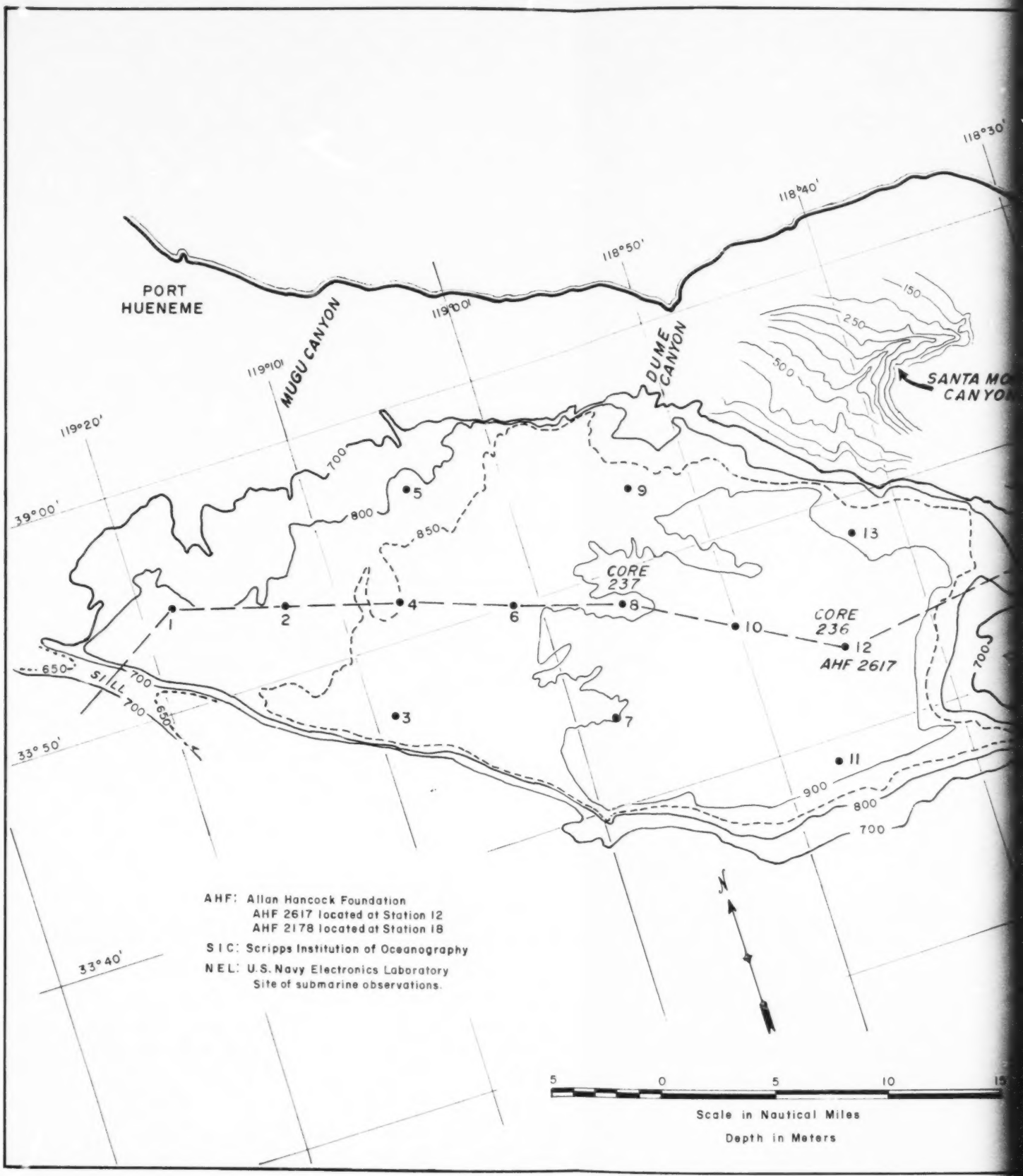
PACIFIC SOUTHWEST REGION SAN FRANCISCO, CALIF.

FIGURE 1


PORT HUENEME
MUGU CANYON
DUME CANYON
SANTA MO CANYON
118°30'
118°40'
118°50'
119°00'
119°10'
119°20'
39°00'
33°50'
33°40'
150
250
500
700
800
850
900
650
SILL
CORE 237
CORE 236
AHF 2617
1
2
3
4
5
6
7
8
9
10
11
12
13
AHF: Allan Hancock Foundation
AHF 2617 located at Station 12
AHF 2178 located at Station 18
SIC: Scripps Institution of Oceanography
NEL: U.S. Navy Electronics Laboratory
Site of submarine observations.
N
5 0 5 10 15
Scale in Nautical Miles
Depth in Meters

WATER QUALITY IN SUBMARINE BASINS

STUDY AREA in the SANTA MONICA and SAN PEDRO BASINS

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FIGURE 2

III. DESCRIPTION OF STUDY

STUDY AREA

The Santa Monica and San Pedro Basins are part of the complex continental borderland that extends from Santa Barbara to Cedros Island off Baja California, and from the California coast to a line 150 miles west of Los Angeles. Figure 1 shows the extent of this region.

The system of basins and ridges that characterize the borderline resulted from a succession of block faulting during the late Miocene, followed by a general downwarping that continued into the post-Pleistocene (2). Seven long primary faults, roughly parallel and interconnected by shorter faults, are believed to exist between the coastline and the continental slope. Steep escarpments from the fault network separate the parallel belts of basins which become progressively deeper with increased distance from land. Some of the intervening ridges extend above the water to form islands such as Santa Catalina and San Clemente, while others are submerged at different depths.

All of the basins are in various stages of filling. Detrital fallout and diffusion of sediment from the shore are the predominant modes in the outer basins, while turbidity currents, which originate in submarine canyons and then spread out across the basin floors, account for most of the fill in the inner basins. It has been estimated (3) that the San Pedro and Santa Monica Basins, which have very flat floors at depths averaging between 850 and 900 meters, have accumulated more than 3000 meters of sediment since their formation 20 million years ago.

For most purposes the two basins may be considered as one, since they are separated only by a topographic high around which the water may circulate freely. Lying immediately adjacent to the present coastline, the two basin system extends from a point near Port Hueneme at the northwest end to a point near Huntington Beach at the southeast end.

The primary sill, which is defined as the lowest point on the basin rim, is located at the southeast end of the San Pedro Basin at a depth of 736 meters. A secondary sill, with a depth of 675 meters, is located at the northwest end of the Santa Monica Basin and permits a flow of water between the Santa Monica Basin and the neighboring Santa Cruz Basin.

The study area lies within the 700 meter contour surrounding the two basins. Figure 2 shows the location of the sills and the extent of the study area.

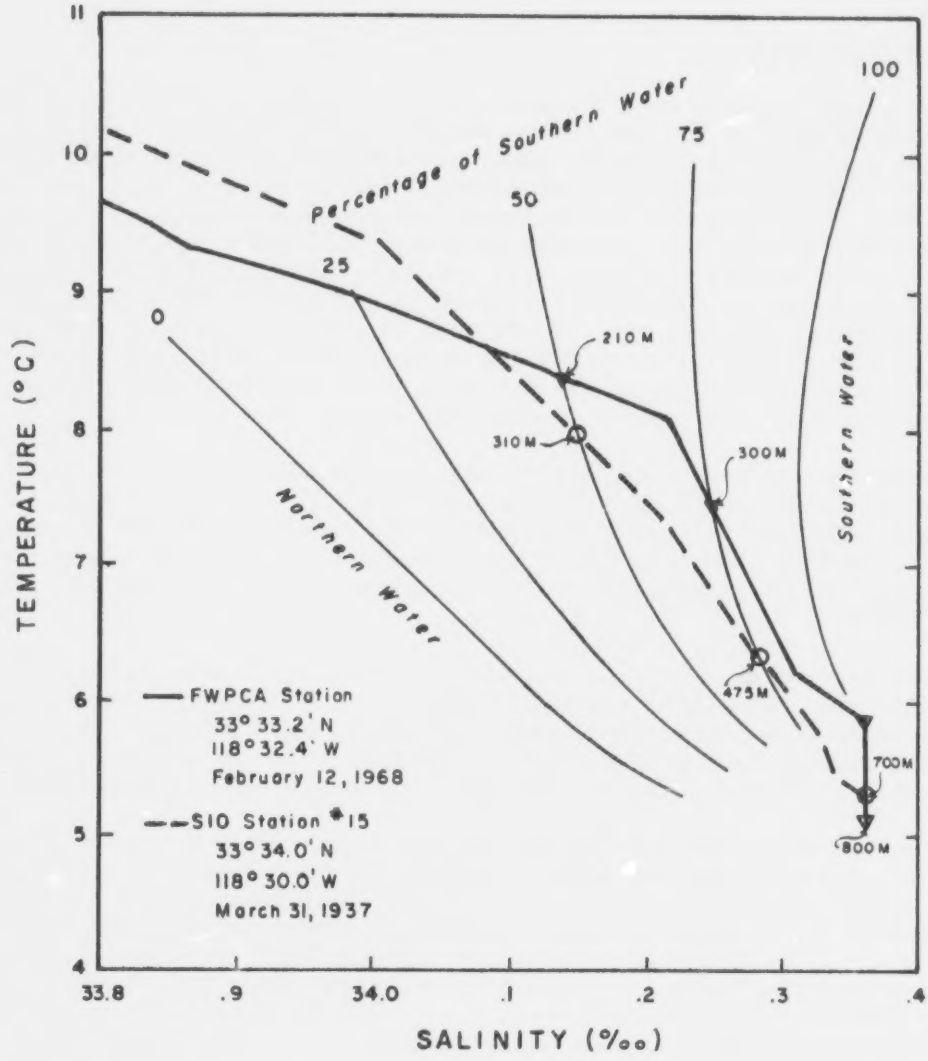
CIRCULATION

The sea overlying the Santa Monica and San Pedro Basins consists of two distinctly different water masses. From the surface to approximately 200 meters the water is characteristic of the California Current, which originates about 200 miles off the Washington coast and moves southeasterly to 25°N at speeds of less than half a knot. As this current passes Point Conception a large eddy is formed over the northern portion of the continental borderland, so that the flow over parts of this region often has a northerly set.

At a depth of 200 to 500 meters the California Current water mixes with a deeper water mass from the south having different characteristics. The northern and southern water masses have been identified (4) by distinctive temperature vs. salinity plots (T-S curves) drawn from a large number of observations made in the 1930's. The relative amounts of each at any level of any station in this area can be readily determined by comparing a T-S curve from the station with the two curves of unmixed water. Figure 3 shows two T-S curves plotted in this manner from data obtained in the San Pedro Basin. These observations were made 31 years apart, but at roughly the same location.

The FWPCA data, taken in February 1968, indicates equal mixing of northern and southern waters at approximately 300 meters. At 500 meters 75% of the water is of southern origin, and within the basin the water is entirely southern. The earlier T-S curve (4), taken in March 1937, shows equal mixing at 200 meters and 75% southern water at 300 meters. Differences in the upper levels may be due to seasonal or periodic changes in the flow and depth of the eddying California Current over the continental borderland. The coincidence of the two curves below 500 meters, and especially within the basins, underscores the secular nature of the deep water characteristics.

Comparisons of temperature, salinity and oxygen values below sill depth in the San Pedro and Santa Monica Basins with those found at the same depth in the other basins show that replacement water enters the two basin system over the sill from the southeast (5). The replacement rate and circulation pattern are not known, but computations based on the oxygen demand of organic matter in the sediments suggest that a complete replacement of water within the basins requires less than two years (6). These conclusions have been supported by recent observations near the floor of the San Pedro Basin, in which current meter measurements and the drift of a dye cloud showed that the bottom water moves in a northerly direction at speeds between 0.01 and 0.02 knots (7).



WATER QUALITY IN SUBMARINE BASINS

TEMPERATURE VS SALINITY
in the
SAN PEDRO BASIN

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FIGURE 3

FIELD STUDY

Sampling Plan

Sampling stations were located at 5 mile intervals along the longitudinal axis of the two basins and at roughly 10 mile intervals along the periphery of the study area. In addition to providing profiles for comparison with past and future observations, the data from the axial stations could be developed into vertical cross sections of oxygen, temperature, salinity and density. Such cross sections would show the structure of the water for each characteristic, reveal areas of anomolous concentrations, and imply circulation and mixing patterns. The peripheral stations, in addition to providing data at specific locations, would aid in developing a three-dimensional view of the water structure as well as show the degree of horizontal homogeneity on the lateral axes. The station locations are shown in Figure 2.

Sampling for dissolved oxygen, temperature and salinity was conducted at 16 to 19 levels at each station. Although dissolved oxygen concentrations were of prime importance in this study, temperature and salinity measurements were required to identify water masses and to understand the physical structure of the water within and overlying the basins.

Nutrient samples were taken near the bottom at 7 stations located along the longitudinal axis, and were analyzed for total and ortho phosphate-phosphorous, organic and nitrate nitrogen, and silicate. Any significant change in these nutrient values from those characteristically found could indicate the effects of changes in the environment.

One method of determining whether the bottom water contained enough oxygen in the past to support benthic life is to examine a core of the bottom sediments. The presence of well mixed sediments and shell remains of burrowing organisms indicates conditions which are favorable to life. Undisturbed layering of sediments and an absence of burrowing organisms suggests an unsatisfactory environment.

During the spring and summer months organic productivity is high and organic detritus forms the most important source of fallout. The siliceous content, which is derived from diatom remains, causes the layer of material that settles during these months to be light colored. In the winter inorganic sediment becomes predominant and produces a dark layer. This alternating layering, or varving, provides an effective time record in undisturbed sediments. Where a formerly favorable environment was altered in such a way as to inhibit life in the sediments, the time of occurrence of the alteration can be determined by counting the varves overlying the well mixed sediment.

One sediment core was taken in each of the two basins to determine the nature and amount of the reported brown flocculent material, and the period over which the lifeless conditions on the basin floors had extended. In the San Pedro Basin the core was taken near the position at which the submarine observations had been made. In the Santa Monica Basin a coring operation was attempted at station 12, which is located on an extension of the axis of the Santa Monica Canyon. A clay layer, however, prevented more than an inch penetration, and an alternate site was selected 10 miles to the northwest at station 8. Because of mechanical considerations and availability of ship time, the cores were taken two months later than the water samples on a second cruise in April 1968.

Sampling Methods

Water samples were taken with 2 liter Nansen bottles. These metal sampling devices are clamped at desired intervals to a 5/32 inch steel hydrowire as it is lowered into the ocean. The clamp on each bottle is located at its base, while the top is held to the wire by a lever actuated pin. When a messenger, or brass weight, is slid down the wire and strikes the lever, the pin is withdrawn and the bottle falls outward and swings upside down around the clamp at its base. This action closes valves at each end and effectively traps a sample of the surrounding water.

The reversing action also releases a second messenger which has been attached near the clamp by another pin mechanism. This messenger slides down to trip the second bottle, which in turn releases a third messenger, and so on. By this method many points in the water column can be sampled almost simultaneously.

Sixteen to nineteen Nansen bottles were used on each cast, depending upon the depth at the station. Because of the particular interest in bottom water, the lowest 5 bottles on each cast were spaced 25 meters apart. At intermediate depths the bottles were spaced 50 and 100 meters apart, the latter separation being the maximum used in any cast.

Each Nansen bottle was equipped with 3 reversing thermometers. Two thermometers were protected from the effects of hydrostatic pressure by glass envelopes while the third was unprotected. After correcting the readings for the effects of thermal changes in both the protected and unprotected thermometers, it was possible to determine both the depth of the observation from the pressure differential and the *in situ* temperature.

As soon as the Nansen bottles were recovered from a cast, the thermometers were read and water samples were drawn for salinity and oxygen analyses. The oxygen samples were drawn with extreme care to avoid entraining air and trapping bubbles, and were immediately preserved with manganous sulphate and alkaline iodide. Salinity samples were sealed in citrate bottles with clamp-on tops and rubber gaskets to prevent evaporation. Nutrient samples were preserved with mercuric chloride and frozen.

A cross check on the depth of the lowest bottle was also made by use of sonic equipment. A "pinger," which emitted regularly spaced signals, was attached to the end of the hydrographic wire and its distance from the basin floor, as well as the actual depth, was recorded on a continuous chart.

Sediment samples were collected with a unique coring device designed by Andrew Soutar and Eric Duffrin of Scripps Institution of Oceanography to sample uncompacted muds and sediments without disturbing even the loose floc at the interface. This device consisted essentially of a weighted box corer measuring 30 cm square and 60 cm in height connected to a hydraulic slowing mechanism.

Figure 4 shows a photograph of the corer. The two doors or shovels, which are connected by arms crossing scissorlike on either side of the box, are tied open during the descent with light twine. When the device has settled on the basin floor and the corer has penetrated into the mud as far as gravity will force it, tension is applied to the winch cable which causes the doors to swing downward and close horizontally under the open bottom of the box. The doors fit tightly against neoprene seals and effectively prevent both sediment and water from draining during recovery.

Once recovered, the box and its enclosed sample were immersed in a CO_2 - isopropyl alcohol bath ($-78^{\circ}C$) to quick freeze the sediment. This prevented further distortion and stopped bacterial action. Views of the coring box, freezing and extraction are shown in figures 5, 6 and 7.

ANALYTICAL METHODS

All sample analyses were made ashore. Dissolved oxygen concentrations were determined by the standard Winkler method and are expressed herein in ml/l, where 1 mg O_2 = 0.7 ml O_2. In an attempt to achieve high resolution, a 0.00625N PAO (phenylarsineoxide) titrating solution was used in a 10 ml burette. For low oxygen values concentrations were consistently reproduced to within 0.01 ml/l. Salinity was measured with an inductive salinometer, and nutrients were determined by the following methods:

a) Silicate: colorometric heteropoly blue.

b) Nitrate-nitrogen: modified Brucine.

c) Organic nitrogen: Kjeldahl digestion with Nesslerization.

d) Orthophosphate-phosphorous: ascorbic acid reduction.

e) Total phosphorous: ascorbic acid reduction followed by digestion with sulfuric acid and ammonium persulfate.

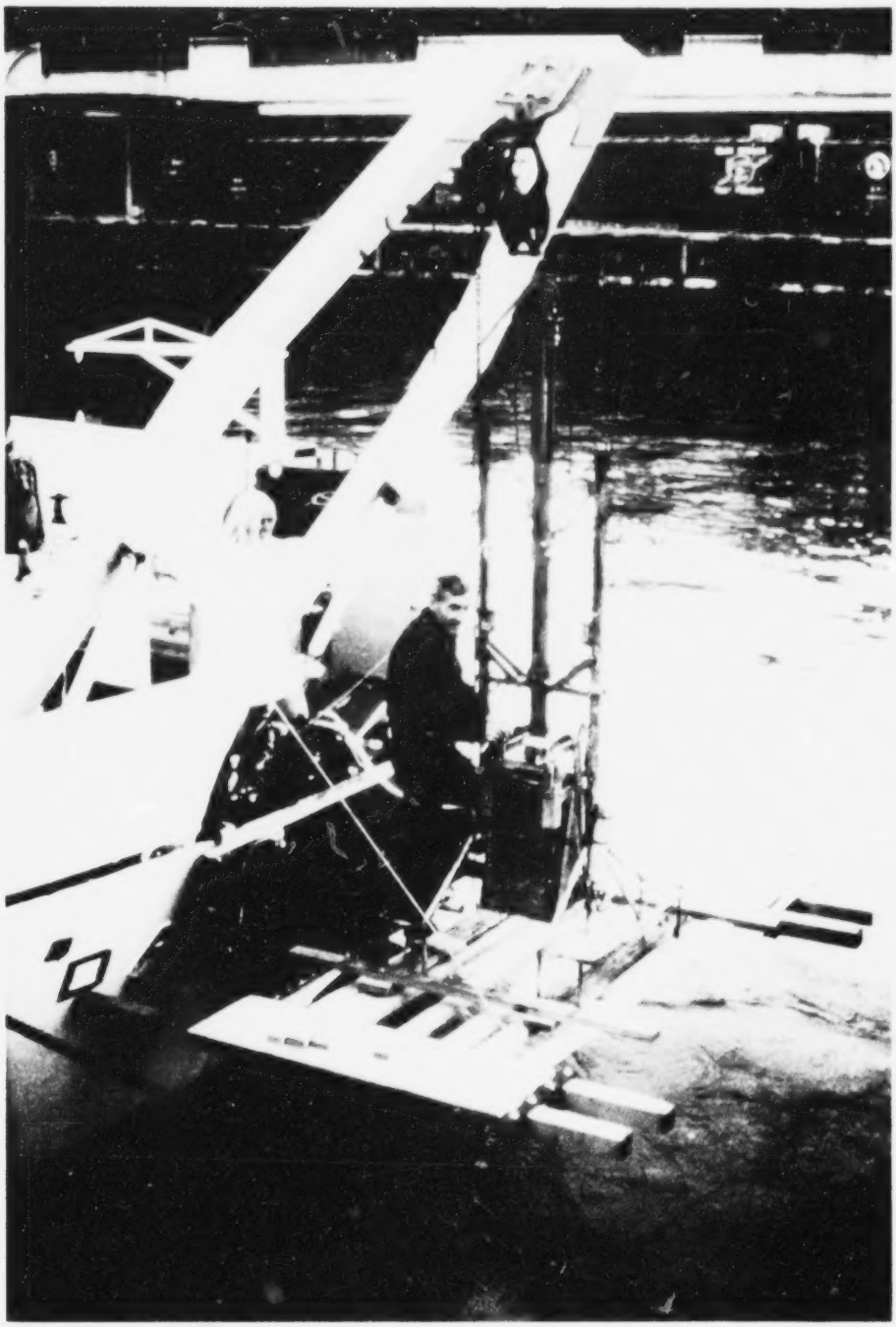


Figure 4. Coring device mounted on the stern of the USC&GSS Davidson.

The cores were prepared for analysis by sawing the frozen samples into vertical sections and making radiographs (X-ray photographs). By this method the superficial distortions produced by sawing, as well as other minor irregularities that might obscure the true layering, were removed.

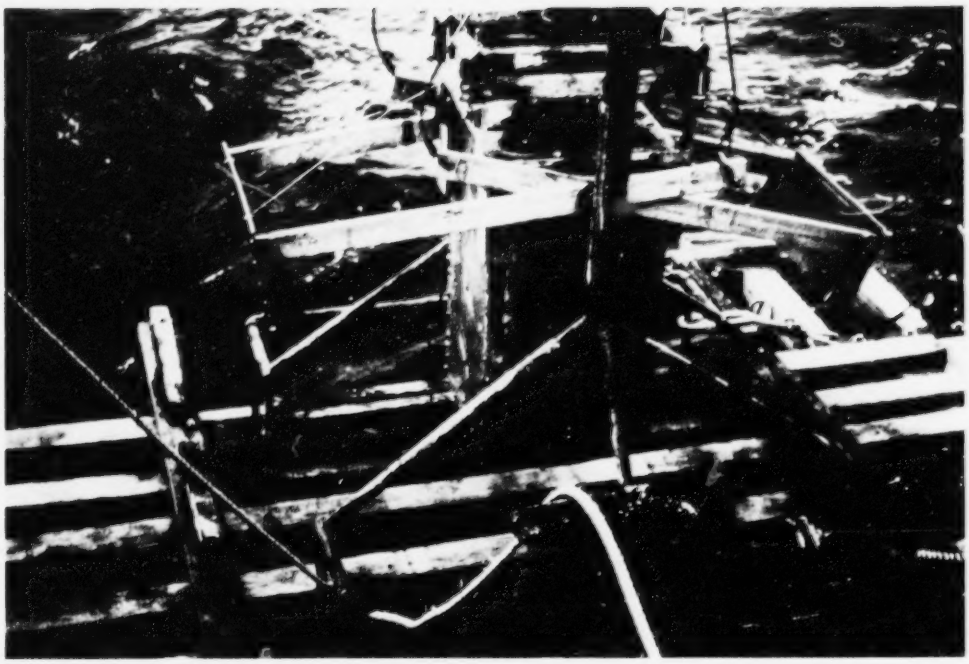


Figure 5. Coring box with doors tied in open position.

Figure 6. Core box with sample being lowered into quick freeze solution.

Figure 7. Frozen core being removed from core box.

IV. STUDY RESULTS

OXYGEN, SALINITY AND TEMPERATURE

In the ocean off southern California the oxygen content decreases from about 6 ml/l in the mixed layer to a fraction of one ml/l in the oxygen minimum zone at a depth of about 700 meters, and then gradually increases with depth to 3 or 3.5 ml/l. The oxygen minimum zone phenomenon is not completely understood, but is generally attributed, at least in part, to the density relationship between oxygen consuming organic detritus and the surrounding water.

In the case of the San Pedro-Santa Monica Basin system, the oxygen minimum zone coincides with the sill depth. Most of the replacement water for the system flows in immediately over the sill, and it is from this source that oxygen replenishment within the basins must be derived. Thus, the oxygen level within the basins should not be higher than that found in the minimum zone, and, because of the topographical restrictions to circulation, it should be somewhat lower.

Figure 8 shows a vertical cross section of the dissolved oxygen along the longitudinal axis of the basin system. Below the sill depth the maximum concentration is about 0.3 ml/l and the minimum is less than 0.1 ml/l. Oxygen concentrations approach zero near the floor at several locations; the average dissolved oxygen concentration in both basins is approximately 0.20 ml/l.

Salinity, temperature and density sections along a longitudinal axis are presented in Figures 9, 10 and 11, respectively. Slight salinity and density domes are apparent at the centers of both basins.

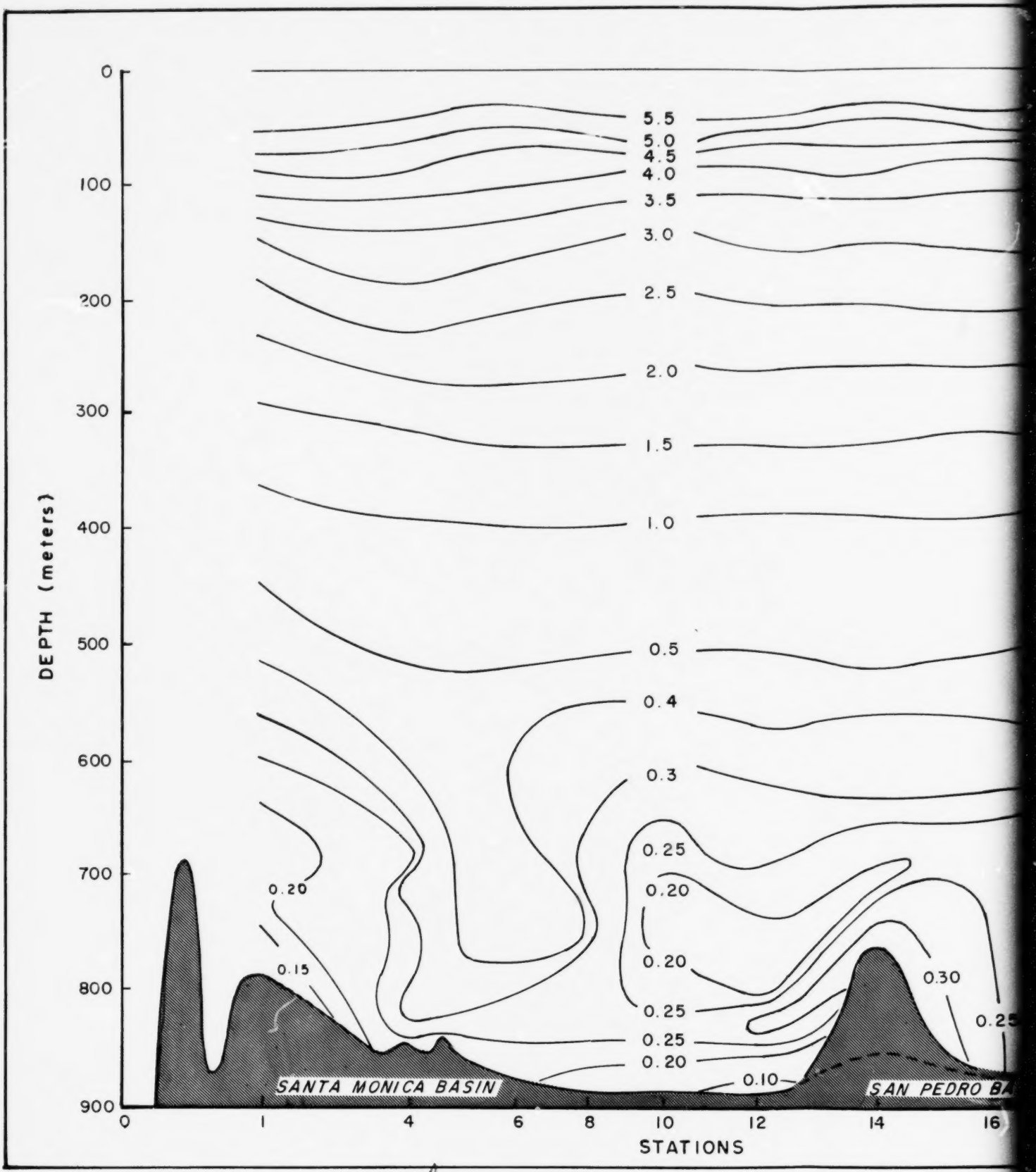
NUTRIENTS

Table 1 lists nutrient concentration at 7 stations near the basin floor. Differences in nutrient concentrations, between stations, may be within analytical error. Nitrate-nitrogen concentrations are below concentrations generally found in seawater.

Nutrient concentrations observed by other investigators are included for comparison.

CORE SAMPLES

Figures 12 and 13 show radiographs of cores 237 and 238, taken at station 8 in the Santa Monica Basin and at a point one mile from station 20 in the San Pedro Basin respectively.


DEPTH (meters)
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SANTA MONICA BASIN
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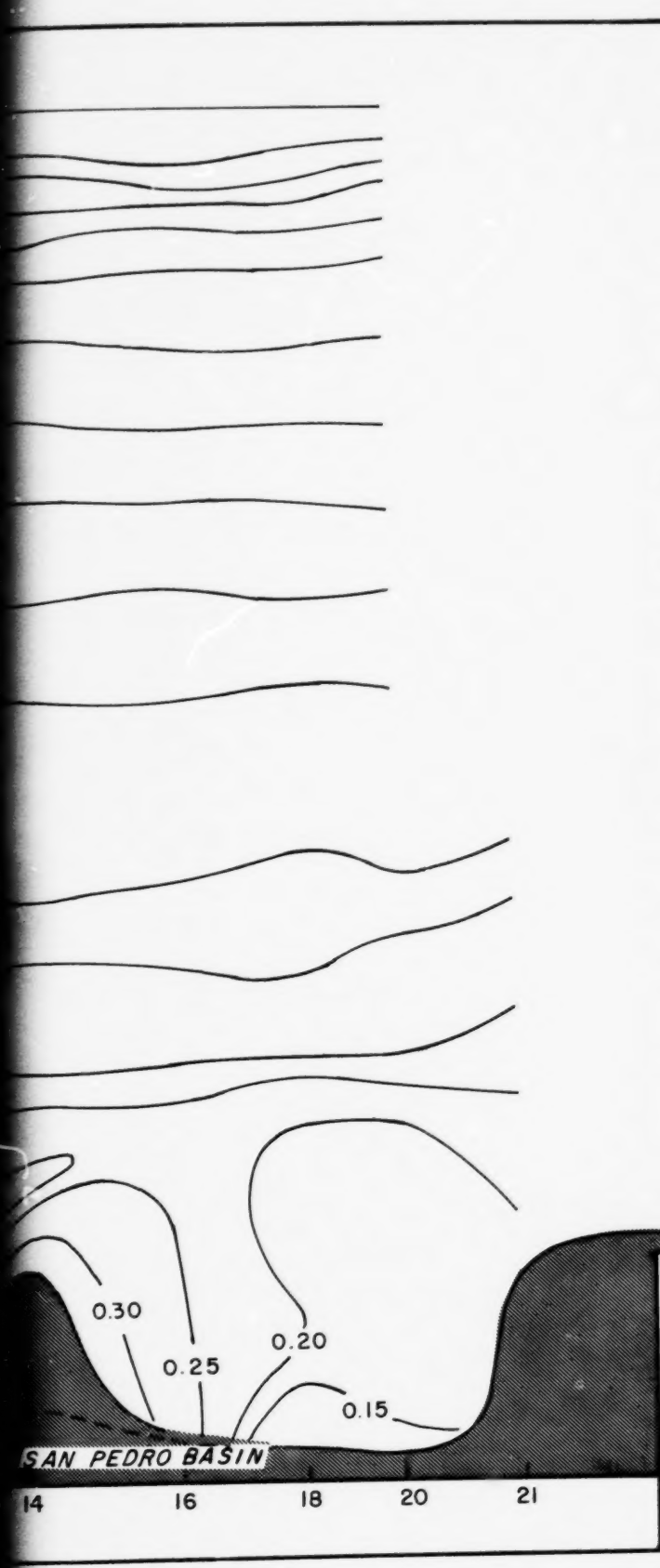
STATIONS

A



WATER QUALITY IN SUBMARINE BASINS

DISTRIBUTION OF DISSOLVED OXYGEN in the SANTA MONICA and SAN PEDRO BASINS

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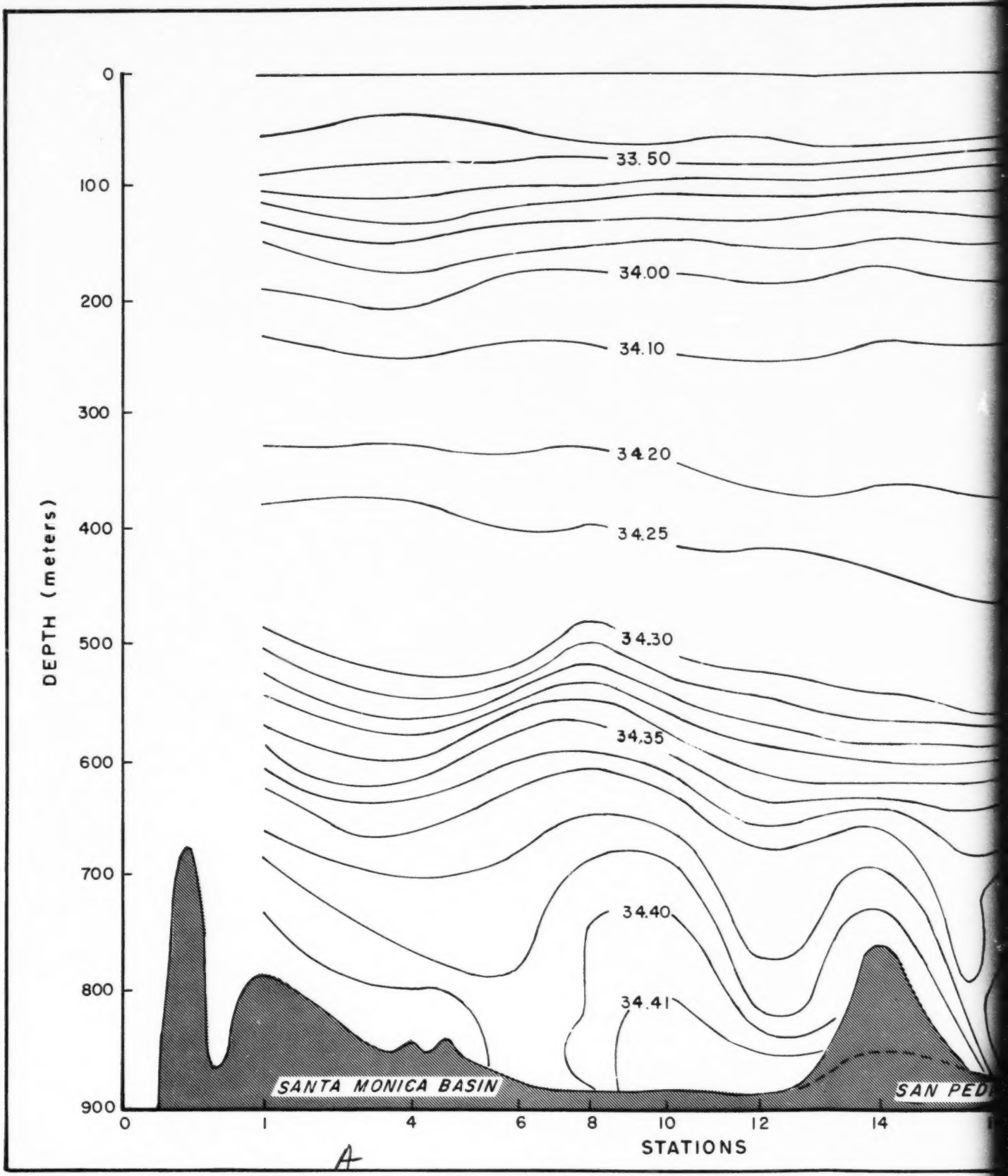
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
PACIFIC SOUTHWEST REGION SAN FRANCISCO, CALIF.

B

FIGURE 8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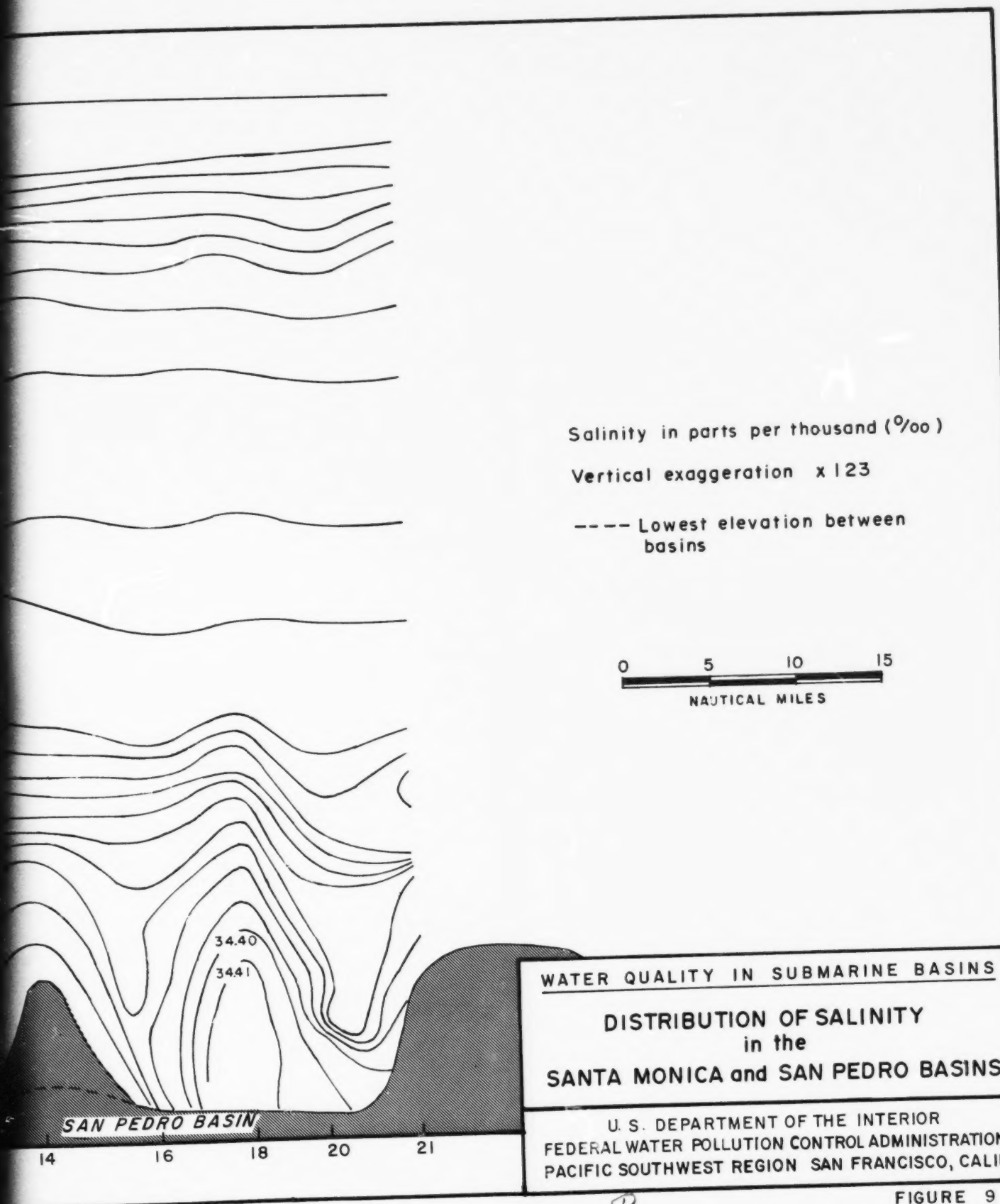

WATER QUALITY IN SUBMARINE BASINS

DISTRIBUTION OF SALINITY in the SANTA MONICA and SAN PEDRO BASINS

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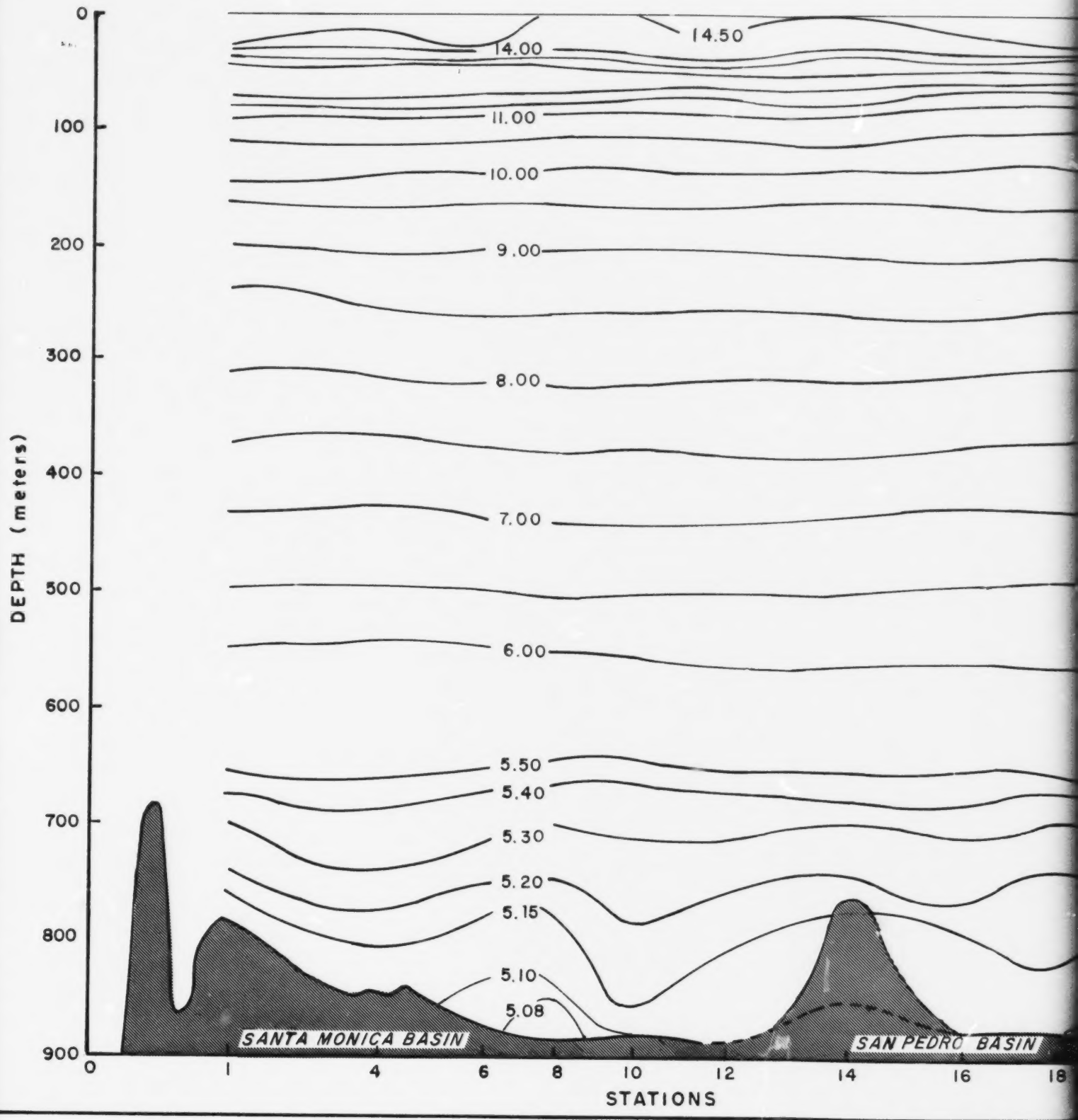
PACIFIC SOUTHWEST REGION SAN FRANCISCO, CALIF.

FIGURE 9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100
200
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DEPTH (meters)
14.50
14.00
11.00
10.00
9.00
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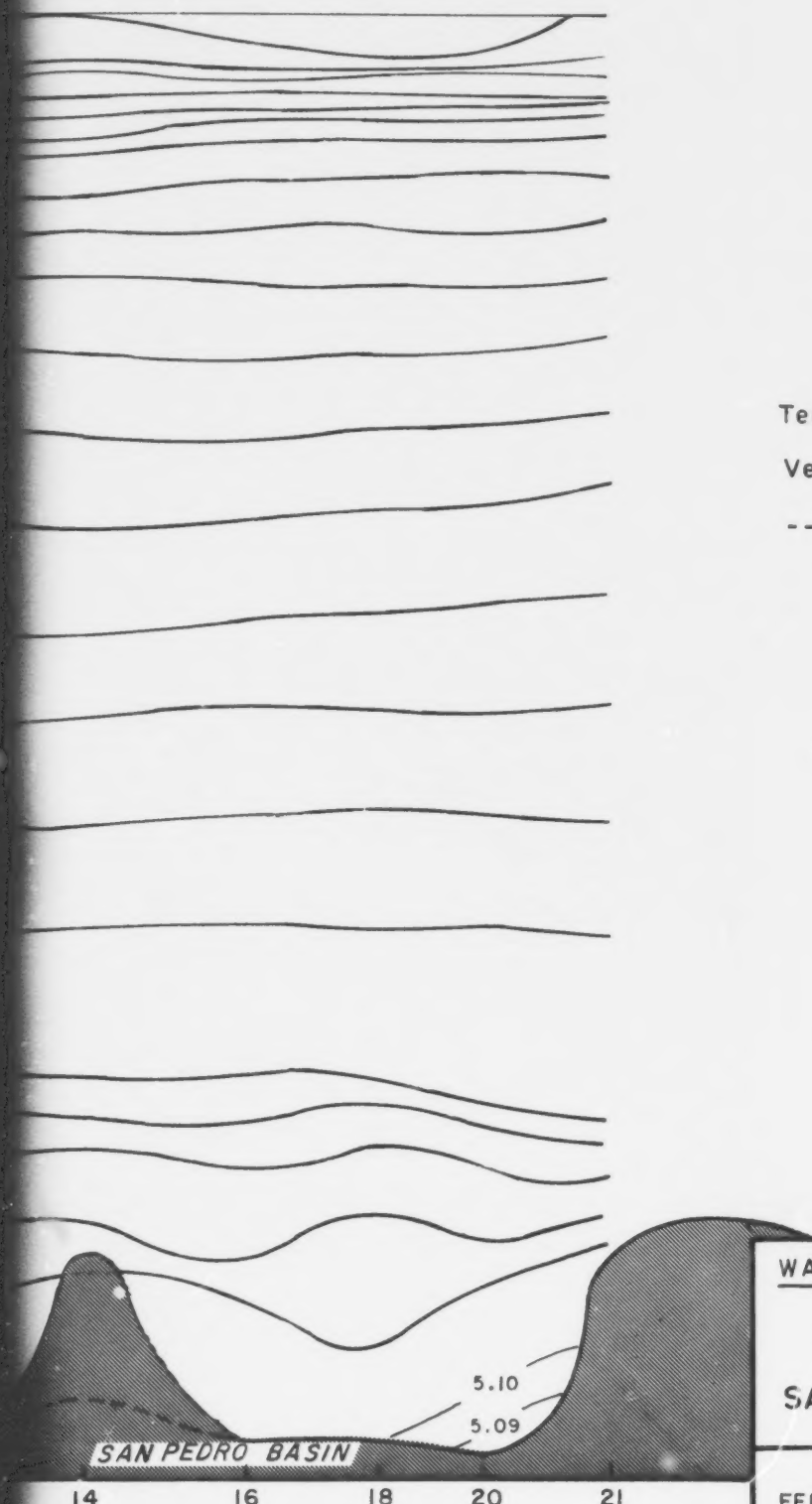
7.00
6.00
5.50
5.40
5.30
5.20
5.15
5.10
5.08
SANTA MONICA BASIN
SAN PEDRO BASIN
0
1
4
6
8
10
12
14
16
18
STATIONS

A



Temperature in degrees centigrade

Vertical exaggeration x 123

---- Lowest elevation between basins

0 5 10 15

NAUTICAL MILES

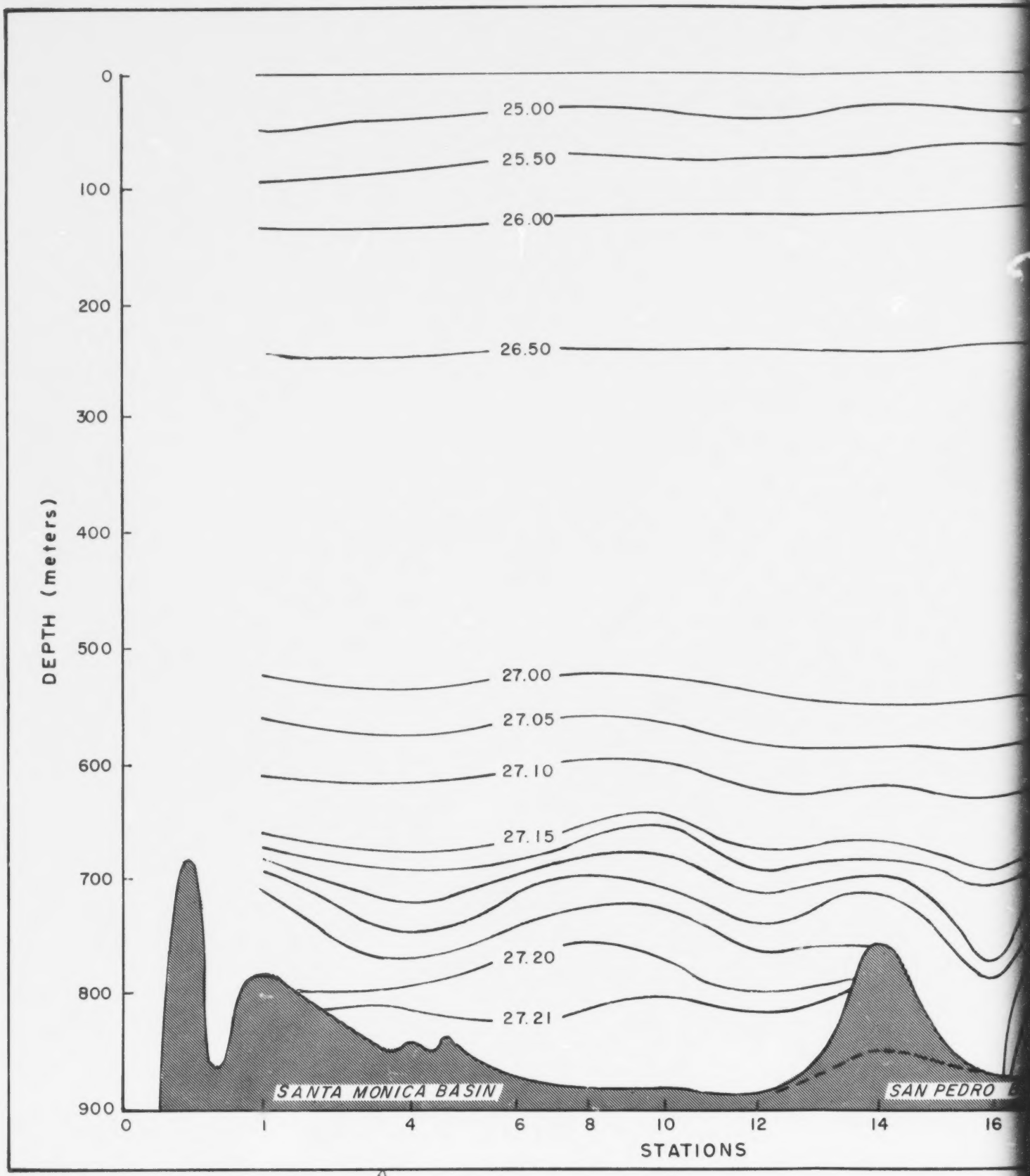
WATER QUALITY IN SUBMARINE BASINS

DISTRIBUTION of TEMPERATURE in the SANTA MONICA and SAN PEDRO BASINS

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
PACIFIC SOUTHWEST REGION SAN FRANCISCO, CALIF.

B

FIGURE 10


0
100
200
300
400
500
600
700
800
900
DEPTH (meters)
25.00
25.50
26.00
26.50
27.00
27.05
27.10
27.15
27.20
27.21
SANTA MONICA BASIN
SAN PEDRO
0
1
4
6
8
10
12
14
16
STATIONS

A

Density units in $\sigma_t = (\rho_{s,t,0} - 1)\, 10^3$

Vertical exaggeration x 123

---- Lowest elevation between basins

0 5 10 15

NAUTICAL MILES

WATER QUALITY IN SUBMARINE BASINS

DISTRIBUTION OF WATER DENSITY in the SANTA MONICA and SAN PEDRO BASINS

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
PACIFIC SOUTHWEST REGION SAN FRANCISCO, CALIF.

B

FIGURE 11

TABLE 1. NUTRIENT CONCENTRATIONS NEAR THE FLOOR OF THE SAN PEDRO AND SANTA MONICA BASINS

Station	Date	Location	Depth (meters)	Total-P (mg/l)	Ortho-P (mg/l)	Total Org-N (mg/l)	NO_3-N (mg/l)	SiO_2-Si (mg/l)
4	11 Feb 68	33°51.7'N 119°07.5'W	833	0.13	0.10	0.11	0.22	2.57
8	11 Feb 68	33°48.7'N 118°55.4'W	876	0.14	0.12	0.13	0.28	2.62
10	12 Feb 68	33°45.4'N 118°51.5'W	880	0.18	0.08	0.23	0.38	2.38
14	12 Feb 68	33°45.5'N 118°34.8'W	700	0.09	0.11	0.11	0.34	2.38
16	12 Feb 68	33°38.1'N 118°29.5'W	871	0.16	0.09	0.10	0.40	2.43
18	12 Feb 68	33°34.3'N 118°24.8'W	848	0.22	0.11	0.12	0.25	2.66
20	13 Feb 68	33°31.0'N 118°21.0'W	872	0.11	0.12	0.12	0.33	2.62
Average	---	---	---	0.15	0.10	0.11	0.31	2.51
NEL 186*	4 Dec 66	33°29.8'N 118°22.1'W	915	---	0.10	---	0.49	2.02
AHF 2617**	1 Apr 54	33°45'N 118°46'W	884	---	0.10	---	0.49	4.41
Typical E. Pacific Ocean Values (9)			750	---	0.10	---	0.48	3.70

*Navy Electronics Laboratory Dive 186 (7), Located 1.5 miles southwest of FWPCA 20.
**Allan Hancock Foundation Station 2617 (6), Located at FWPCA 12.

Figure 12. Radiograph of Core 237, taken at 33°49.8'N 118°55.5'W, at Station 8. Water depth 876 meters.

Figure 13. Radiograph of Core 238, taken at 33° 29.8'N 118° 21.7'W, one-half mile south of Station 20. Water depth 881 meters.

Core 237 shows a fine layering in the upper half that is thought to be annual. The number of varves indicate that burrowing organisms have been absent in the sediment for at least 50 years.

The radiograph of Core 238 is not quite as clear. Freezing requirements for the unsuccessful core taken at Station 12 and for Core 237 depleted the supply of CO_2 and isopropyl alcohol to the extent that it became necessary to slow freeze Core 238 after completing the cruise. This process produced excessive ice crystals which partially obscured the modes of sedimentation.

The near surface portion of the core shows distinct layering for a period of about 12 years. The lower portion appears to be extensively homogenized and to contain numerous burrowings.

Each of the samples contained a few worm tubes on the surface, and none showed any evidence of the fine brown flocculent material reported by the observers in the deep submersible vehicle. In each case the surface layer consisted entirely of the green mud that is characteristic of the basin floors. The same condition was observed on the surface of the first unsuccessful core.

V. DISCUSSION

COMPARISON OF WATER CHARACTERISTICS WITH EARLIER DATA

Figures 14 through 16 compare salinity, oxygen and temperature profiles taken in February 1968, at station 17 in the San Pedro Basin with data taken in the same vicinity in 1937 (4). At depths below 600 meters none of these parameters show significant change. Salinity, dissolved oxygen and temperature observations at station 12 for the February 1968 cruise are compared with similar observations taken in 1954 (6) in Figures 17 through 19. Again, at depths below 600 meters, there are no significant differences. At station 18 at a depth of 750 meters, salinity is 0.11o/oo (parts per thousand) higher than found in 1952 (5). Salinity differences may be due, in part, to differing analytical methods. Internal circulation of basin water may also cause some variation. Low dissolved oxygen concentrations, reported in 1937, again in 1954, and observed in 1968 suggest that basin waters have contained low concentrations of oxygen for at least 30 years.

Nitrate and ortho-phosphate concentrations are comparable with values reported by others (6) (7), and with concentrations generally observed in seawater (8).

SEDIMENT CORES

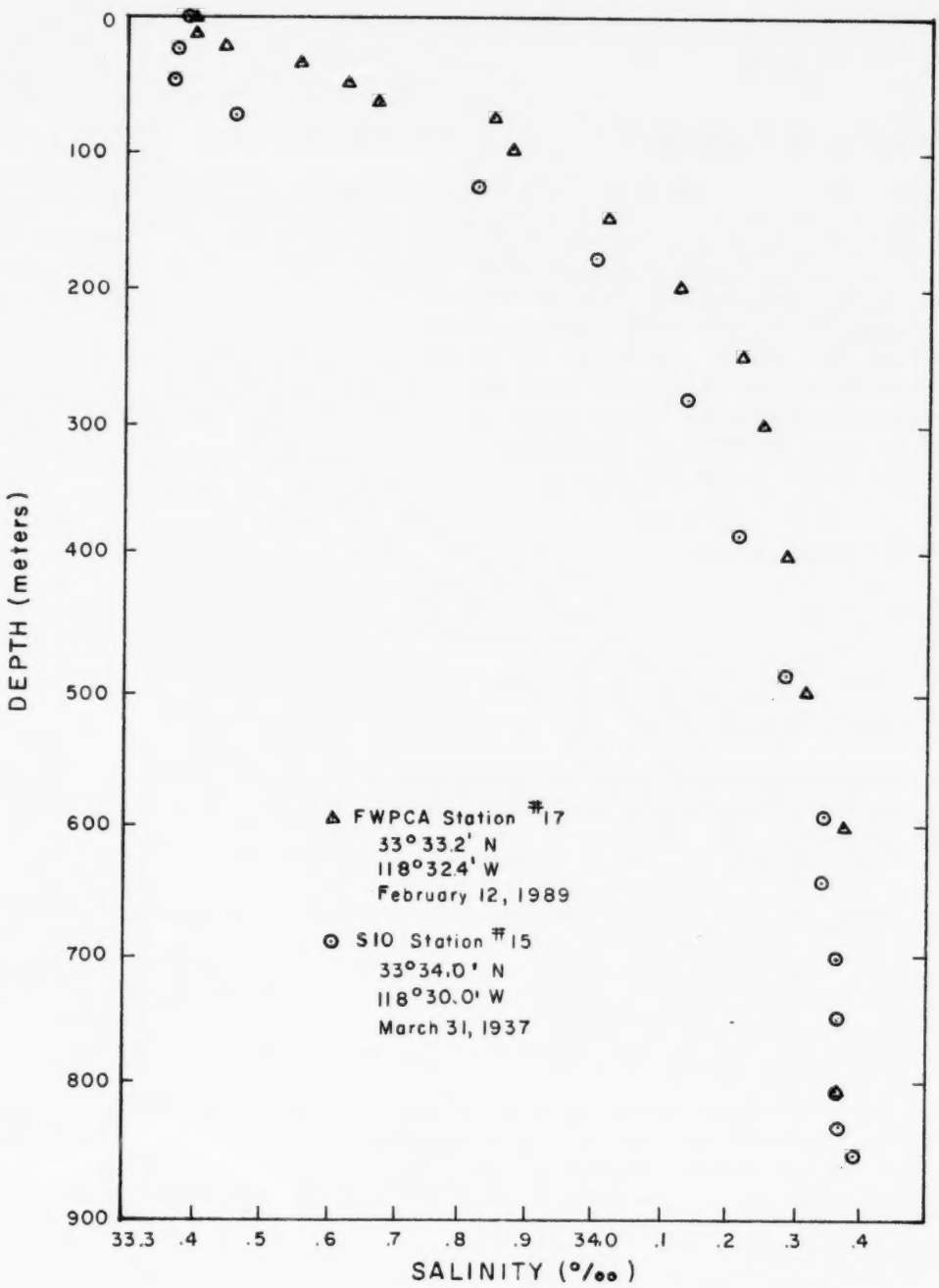
The undisturbed varving of the Santa Monica Basin sediment clearly shows the absence of burrowing organisms for many years. In the San Pedro Basin the record is the same for the past 12 years, but the crystallization in Core 238 prevents conclusions about the record prior to that time.

The presence of worm tubes on the surface of each of the three samples does not necessarily contradict the implication of lifelessness by the varving. Emery (3) states that most samples from these basins have contained empty tubes of certain species of polychaete and serpuled worms, but suggests that these worms are probably vegetative or nonreproductive and reach the bottom from large populations on the side slopes.

The one centimeter thick layer of fine brown flocculent material observed during NEL dives 186 and 187 is unexplained. Not only did the three cores fail to reveal a trace of the floc, but since the initial submarine observations it has not been sighted during any subsequent dives (10).

DISSOLVED OXYGEN

The average dissolved oxygen concentration in the basin waters is approximately 0.20 ml/l. This supply is replenished from water flowing into the basins at sill depth with a content of approximately 0.30 ml/l. Organic sediments, which are thought to be the predominant consumer, have been shown to be capable of exerting sufficient demand to deplete all of the oxygen below the sill depth within two years (6, 9).

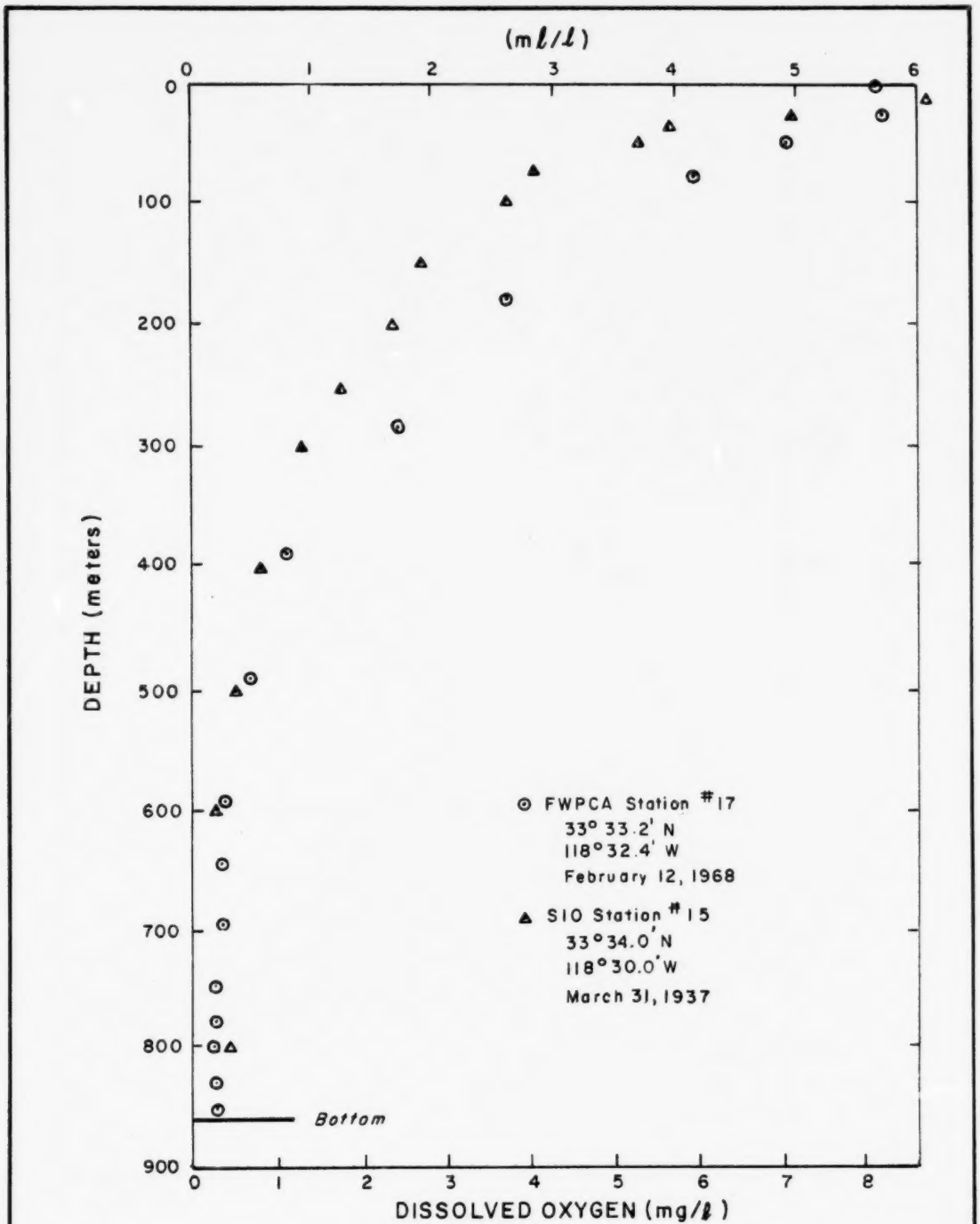


WATER QUALITY IN SUBMARINE BASINS

SALINITY PROFILES in the SAN PEDRO BASIN

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
PACIFIC SOUTHWEST REGION SAN FRANCISCO CALIF.

FIGURE 14

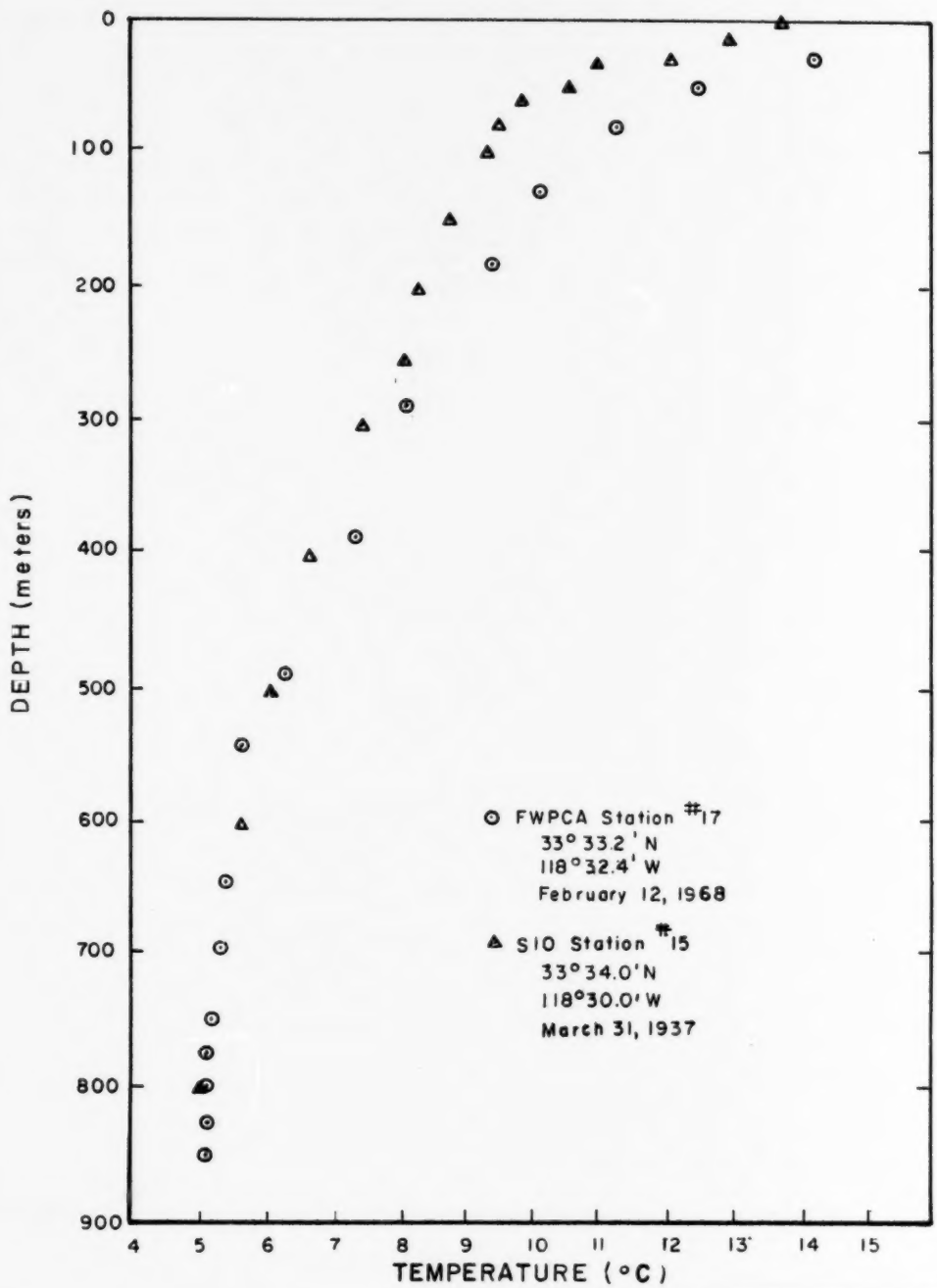


WATER QUALITY IN SUBMARINE BASINS

DISSOLVED OXYGEN PROFILES in the SAN PEDRO BASIN

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
PACIFIC SOUTHWEST REGION SAN FRANCISCO, CALIF.

FIGURE 15

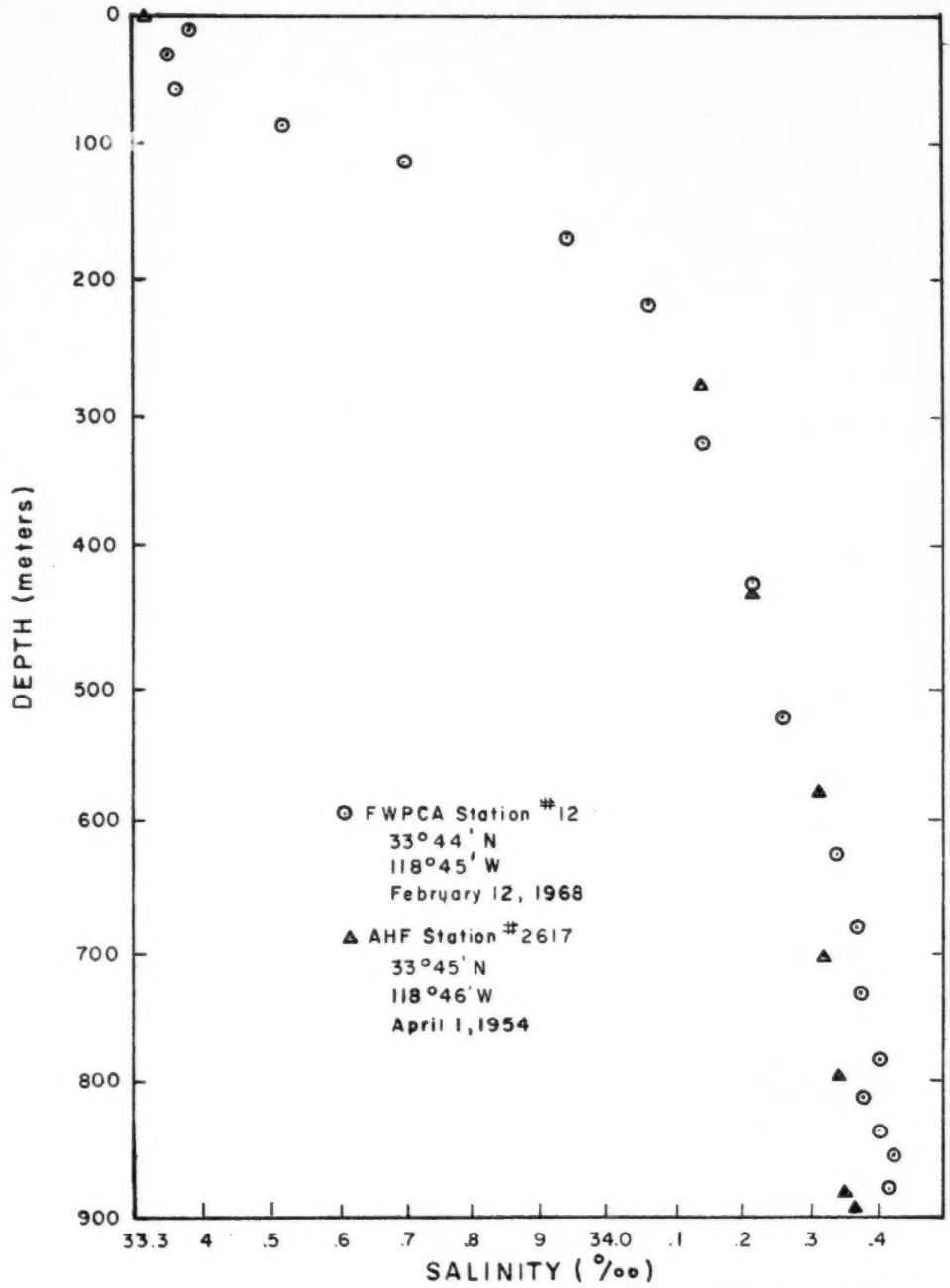


WATER QUALITY IN SUBMARINE BASINS

TEMPERATURE PROFILES in the SAN PEDRO BASIN

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
PACIFIC SOUTHWEST REGION SAN FRANCISCO, CALIF.

FIGURE 16

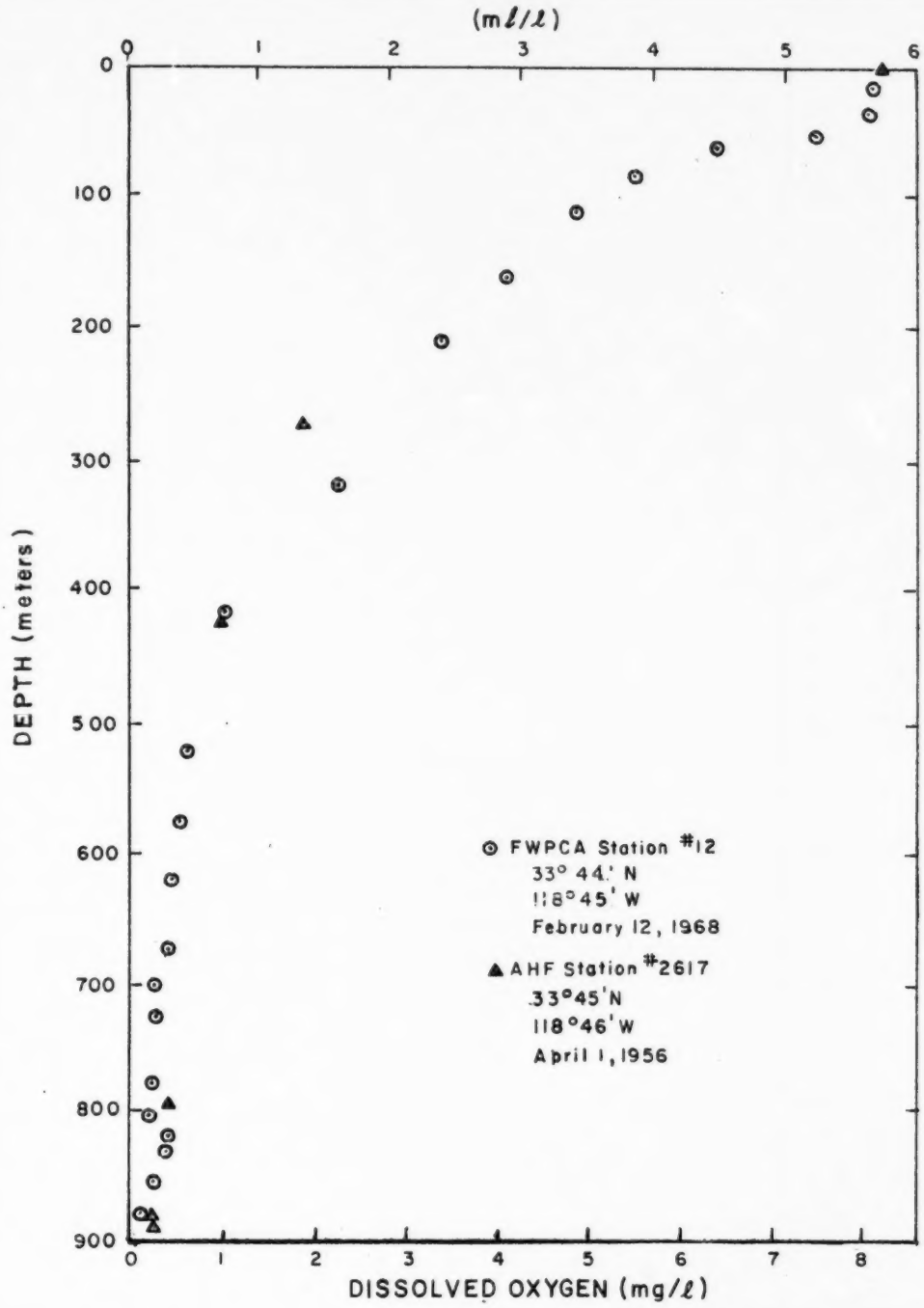


WATER QUALITY IN SUBMARINE BASINS

SALINITY PROFILES in the SANTA MONICA BASIN

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
PACIFIC SOUTHWEST REGION SAN FRANCISCO, CALIF.

FIGURE 17

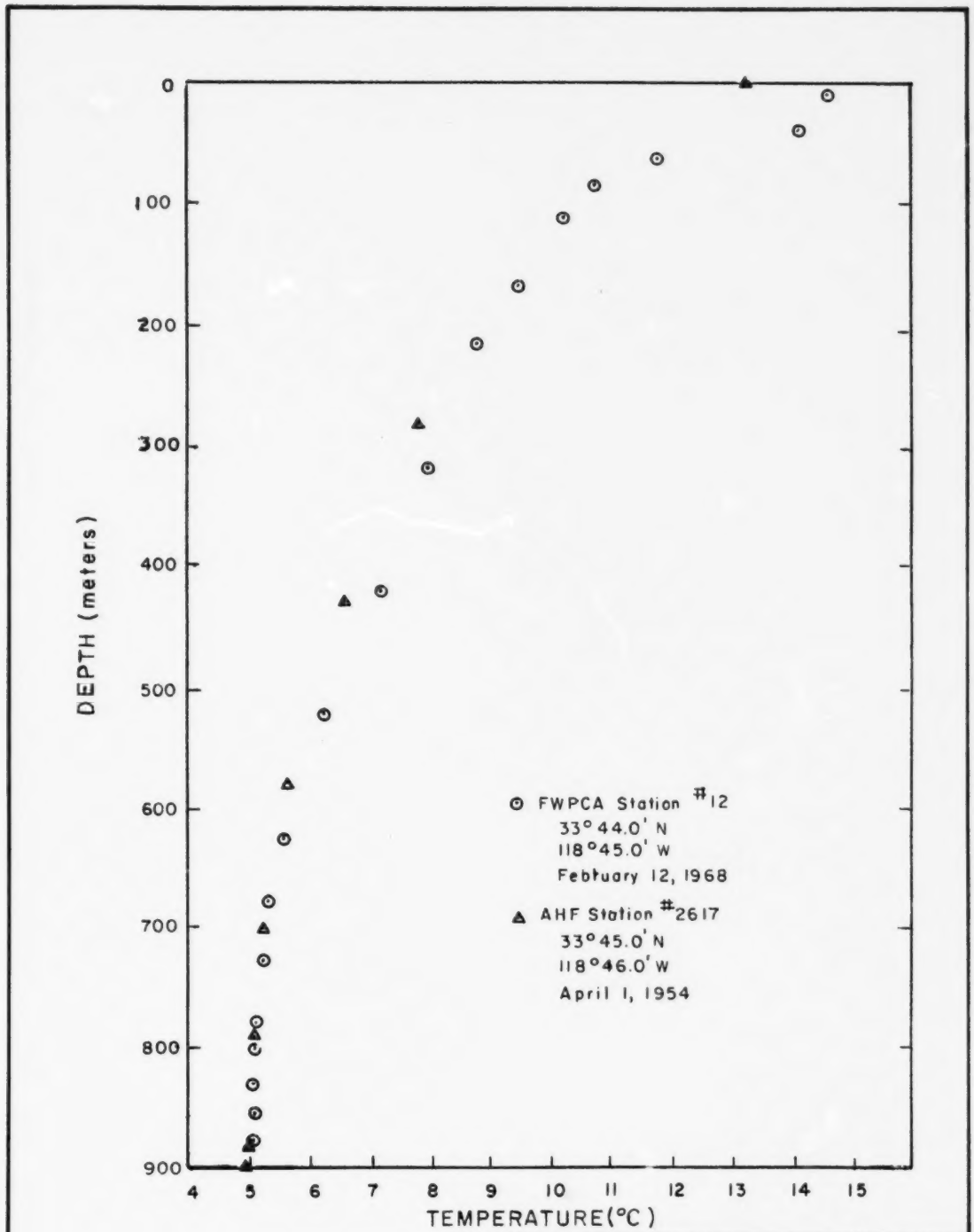


WATER QUALITY IN SUBMARINE BASINS

DISSOLVED OXYGEN PROFILES in the SANTA MONICA BASIN

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
PACIFIC SOUTHWEST REGION SAN FRANCISCO, CALIF.

FIGURE 18



WATER QUALITY IN SUBMARINE BASINS

TEMPERATURE PROFILES in the SANTA MONICA BASIN

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
PACIFIC SOUTHWEST REGION. SAN FRANCISCO, CALIF.

FIGURE 19

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